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THE INVASIVE CORAL *TUBASTRAEA COCCINEA* (LESSON, 1829): IMPLICATIONS FOR NATURAL HABITATS IN THE GULF OF MEXICO AND THE FLORIDA KEYS.

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SHORT PAPERS AND NOTES

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THE INVASIVE CORAL *TUBASTRAEA COCCINEA* (LESSON, 1829): IMPLICATIONS FOR NATURAL HABITATS IN THE GULF OF MEXICO AND THE FLORIDA KEYS.—The impact of nonnative, or exotic, species is considered to be a leading cause of native-species extinction and overall habitat degradation (Simberloff et al., 1997). There is also increasing economic concern about the establishment and spread of invasive species. Besides the intrinsic loss of ecologic services and values that invasive species may cause, the cost to remove exotic species that have become naturalized can be prohibitive. For instance, in the United States the economic impact of invasive species is estimated at about \$120 billion per year (Pimentel et al., 2000). The invasion of nonnative species is often cited as the second-largest ongoing global ecological disaster, after climate change (Wilson, 1997).

In the marine realm, there is increasing evidence that oceanic warming can facilitate the invasion of nonindigenous species (Parker and Dixon, 1998; Stachowicz et al., 2002a; Crickenberger and Moran, 2013), portending doom to some types of communities. This threat of exotic invasions is well documented in many marine and coastal ecosystems (Ruiz et al., 1997), but with the exception of lionfish in the Caribbean (Albins and Hixon, 2008, 2011; Lesser and Slattery, 2011; Albins, 2013; Green et al., 2012; Hackerott et al., 2013), the presence and effects of invaders on coral reefs have rarely been considered (but see Coles and Eldredge, 2002; Smith et al., 2004 for Pacific examples). Here we report on the continued expansion of an invasive scleractinian coral species in the Gulf of Mexico (GOM) and the Florida Keys and comment on the possibility of its introduction to natural habitats throughout the region.

The orange cup coral *Tubastraea coccinea* (Lesson, 1829) is the most widely distributed species of scleractinian coral in tropical regions of the Pacific and Atlantic oceans (Cairns, 1994). Presently, *T. coccinea* is known to have a pan-tropical distribution (Wood, 1983; Cairns, 2000; Fenner and Banks, 2004; Pagad, 2007), occurring in local populations in Bora Bora (the type location of Lesson, 1829), Hawaii (Maragos, 1995), the eastern Pacific (Wilson, 1990; Reyes-Bonilla et al., 1997; Glynn et al., 2008), the

Galápagos (Wells, 1982; Cairns, 1991), Costa Rica and Colombia (von Prahl, 1987), the Red Sea and Arabian Sea (Sheppard and Sheppard 1991), Brazil (Figueira de Paula and Creed, 2004; Sampaio et al., 2012), western Africa (Laborel, 1974), the greater Caribbean basin (Cairns, 2000), the western Caribbean (Fenner, 1999), and now the GOM, Florida, and the Bahamas (Fenner, 2001; Fenner and Banks 2004; Sammarco, 2007).

Tubastraea coccinea, an azooxanthellate coral, is cosmopolitan and commonly found in both reef and nonreef environments (Wood, 1983; Wellington and Trench, 1985; Sammarco et al., 2010). It is a hermaphroditic, brooding species (Harrison and Wallace, 1990) capable of producing larvae through sexual and asexual means (Ayre and Resing, 1986). Colonies of *T. coccinea* are generally found as small plocooid clumps, which are formed by extratentacular budding of the parent colony. Cairns (2000) reported a depth range of 0.3–37 m for *T. coccinea* in the western Atlantic. The earliest record of the genus *Tubastraea* in the western Atlantic was from 1943, with the first reported specimens of *T. coccinea* documented in 1951 (Cairns, 2000). Cairns (2000) noted that specimens were attached to the hulls of ships and that this was the likely vector for introduction into the Atlantic. Soon after the initial introduction, *T. coccinea* increased its range and abundance throughout most of the Caribbean (Cairns, 2000). Fenner and Banks (2004) noted that the pattern of spread of *T. coccinea* in the western Atlantic was similar to the spread of the progressive die-off of the regular echinoid *Diadema antillarum* from a water-borne pathogen, suggesting dispersal of larvae by currents (see Lessios et al., 1984). More recently, Sammarco et al. (2010) reported colonies of *Tubastraea micranthus* (Ehrenberg 1834) on an oil-and-gas platform in the GOM and suggested that, because of its sexual and asexual reproductive strategies, it might pose an invasive threat similar to that of its congener *T. coccinea*.

Fenner (2001) considered *T. coccinea* to be an opportunist and early colonizer, and it is commonly found as a member of the fouling community. In the GOM it is a significant benthic constituent on oil and gas platforms (Sammarco et al., 2004). In Brazil it had originally (and only recently) been identified on oil and gas platforms and on protected, rocky substrates (Figueira de Paula and Creed, 2004).

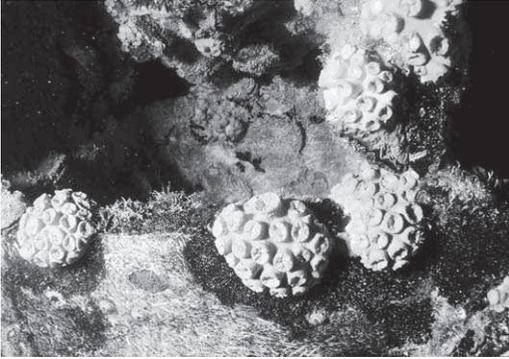


Fig. 1. Plocoid colonies of *Tubastraea coccinea* growing on the outer surface of the *Aquarius* underwater habitat at Conch Reef in the Florida Keys National Marine Sanctuary. Photo courtesy of Steven Gittings.

Now, however, it is found outcompeting native corals on rocky reefs in southeastern Brazil (Creed, 2006; Lages et al., 2011; Riul et al., 2013), where it has been reported to cause necrosis and deformation of native reef-forming coral species (Santos et al., 2013). In Jamaica, where it has been observed for more than four decades (Wells, 1973), it is a common constituent of artificial substrates such as the undersides of buoys (W. F. Precht, personal observation from Discovery Bay) but has not become naturalized in native reef habitats. Along the Florida Keys it is commonly found on large, artificial structures including the *Aquarius* underwater habitat at Conch Reef (Fig. 1) and vessels intentionally sunk as artificial reefs (Shearer, 2009). Numerous isolated colonies of *T. coccinea* have recently been identified on natural reef hard bottoms adjacent to the *Aquarius* (W. F. Precht, personal observation). These observations are consistent with the hypothesis that occupation of primary space by native species is a key to enhancing invasion resistance of exotic species in benthic marine communities (Stachowicz et al., 2002b). In some areas of the Caribbean, however, *T. coccinea* species has become a common constituent of the reef fauna (Cairns, 2000).

At present, *T. coccinea* is the only exotic scleractinian known in the western Atlantic that appears to be expanding its range (Fenner and Banks, 2004). This is quite different from other known coral introductions, such as *Fungia scutarria* in Discovery Bay, Jamaica (Bush et al., 2004). The occurrence and distribution of *T. coccinea* in the GOM suggests that it was possibly introduced into the Gulf by ships or through the transit of oil and gas platforms (Fenner, 2001; Sammarco et al., 2004; Sammarco, 2007). Since

then, the recent, rapid expansion of *T. coccinea* on oil and gas platforms throughout the northern GOM demonstrates the dispersal potential of a benthic invertebrate with planktonic larvae (Fenner and Banks, 2004; Sammarco et al., 2004; Glynn et al., 2008). It is also possible that the warming of sea temperatures throughout the region has facilitated the recent northward expansion of this and other coral species [Zimmer et al., 2006; see also Precht et al. (2014) for discussion of temperature-related range expansions and contractions of corals]. Margolin (2012) noted that in laboratory experiments *T. coccinea* showed little growth response to decreased pH, indicating that this species might gain an advantage over other scleractinian corals under future predicted levels of ocean acidification.

Although it is present in considerable numbers on artificial substrates throughout the GOM and Florida Keys, *T. coccinea* has rarely been sighted on reefs or in other natural habitats (Fenner, 2001). On reefs at the Flower Garden Banks no *Tubastraea* was observed in the 1980s (Bright et al., 1984); however, in 2002 *T. coccinea* was documented for the first time on natural substrates at the East Flower Garden Bank (originally reported in Sammarco et al., 2004; see also Fenner and Banks, 2004; Hickerson et al., 2008; Schmahl et al., 2008). Because *T. coccinea* is generally absent from areas of dense coral growth (Wood, 1983), and given the currently high levels of coral cover measured at the Flower Garden Banks (Aronson et al., 2005), we do not expect *Tubastraea* to become dominant on those reefs, at least in the short term. There are, however, some 33 other named topographic features (banks) throughout the GOM that support a lower cover of scleractinian corals (Rezak et al., 1985) and could serve as receptors for recruitment and establishment of this species. In 2004, over 50 colonies of *T. coccinea* were removed from natural substrates on a peak at Geyer Bank by staff of the Flower Garden Banks National Marine Sanctuary (FGBNMS). In May 2007, up to 100 colonies were observed on the same peak at Geyer Bank, and two colonies were documented at Sonnier Bank (Schmahl et al., 2008). However, during recent surveys in September 2012, FGBNMS divers (including ELH) observed thousands of colonies thriving on the substrate on the shallow-most cap of Geyer Bank at ~35-m depth. This increase in the abundance of *T. coccinea* on Geyer Bank was greater than an order of magnitude and occurred in less than 5 yr. In July 2011, Hickerson et al. (2012) documented a large overhang at the West Flower Garden Bank with upward of 75 *Tubastraea* sp. colonies. Only

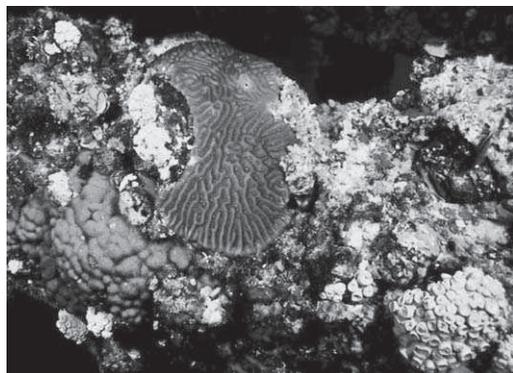


Fig. 2. Numerous isolated colonies of *Tubastrea coccinea* competing for space with an array of epibenthic biota observed on the support structures of an oil and gas platform in the Gulf of Mexico. Note the zone of mortality on the brain coral *Diploria strigosa* and its relationship to a colony of *T. coccinea*. It is unknown if this *T. coccinea* was responsible for the mortality through interspecific aggression or if it opportunistically recruited to the available space created by the mortality. If it is the former, the implications for natural reef habitats throughout the region could be significant. Photo courtesy of Greg Boland.

1 yr later, in August 2012, ~250 colonies were removed from that same outcropping by FGBNMS staff. In addition, two colonies were removed from Stetson Bank, a third topographic feature within the FGBNMS boundaries.

The introduction of exotic corals, transported by fouled vessels, oil and gas platforms, artificial reef structures, or ballast water, coupled with their life history that includes a proclivity for both sexual and asexual recruitment, could be a recipe for disaster. Once established, these corals could also use the ~3000 oil and gas platforms in the northern GOM and the string of sunken artificial reefs in the Florida Keys as stepping stones for expansion on natural substrata (Fofonoff et al. 2003; Sammarco et al., 2004; Sammarco, 2007; Shearer, 2009; Sheehy and Vik, 2010). Presently *T. coccinea* is thriving on High Island A389A, a gas platform located within the boundary of the FGBNMS (Hickerson and Schmahl, 2005). Although *T. coccinea* has become naturalized on some reefs in the Caribbean, at present these exotic corals have had only a minimal impact on reefs and banks in the northern GOM and the Florida Keys (but see Fig. 2). Whether these exotic corals will compete in earnest for available space and become dominant features on reefs of the Flower Garden Banks or the named reefs in the Florida Keys and other natural habitats, however, remains a question for the future. In the meantime, we need to be vigilant in reporting and actively removing exotics invasions from

these native reef habitats (see Hulme, 2006). Clearly, a precautionary approach to limit the potentially harmful effects of these invasive species on natural reef habitats is an important management approach (Wittenberg and Cock, 2001). Once these invaders are established, there may be no viable management action or cure plan (Myers et al., 2000) that can eliminate them from fragile reef ecosystems.

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